PROCEEDINGS

OF THE

AMERICAN PHILOSOPHICAL SOCIETY,

HELD AT PHILADELPHIA.

VOL. XX. JANUARY TO JUNE, 1882. No. 111.

## *On the Origin and Drainage of the Basins of the Great Lakes. By J. S. Newberry.*

(*Read before the American Philosophical Society, November 4, 1881.*)

Having lived for half my life on the shores of Lake Erie, and beginning my geological studies there at an early age, the mode of formation of this water basin naturally became a subject of observation and thought with me. Subsequently, I for ten years owned a country place on one of the islands near the west end of the lake, and during the summer residence of my family there I had a more satisfactory opportunity for the study of the structure of these islands than can be enjoyed by any one now, since some of the most striking cliffs and rock surfaces have been quarried away or covered with buildings.

The interest which I acquired in the subject also led me to visit and examine with some care the whole chain of lakes, and to follow this line of drainage from Duluth, Lake Superior, to its present outlet at the mouth of the St. Lawrence, and its ancient one at New York.

The results of the observations thus made were communicated to the public in "*Notes on the Surface Geology of the Basin of the Great Lakes*" (Boston Natural Historical Society, 1862); "*Geological Survey of Ohio, Report of Progress for 1869;*" "*The Surface Geology of the Basin of the Great Lakes and the Valley of the Mississippi*" (Lyceum of Natural Historical Society, New York, 1869); "*The Surface Geology of Ohio*" (Report of Geological Survey of Ohio, Vol. ii, 1874); "*The Geological History of New York Island and Harbor*" (Popular Science Monthly, 1878).

In the progress of these investigations, I discovered what had not before attracted attention, that (1), at one time the eastern and middle portions of the continent stood considerably higher above the ocean than at the present time; (2), that an extensive system of drainage lines which once traversed the continent had been subsequently more or less filled up and obliterated, generally by the drift of the Ice period; (3), that our modern rivers had often deserted their ancient valleys altogether, and flowed some-

times hundreds of feet above their former beds; and (4), that glaciers had once occupied the basins of our great lakes, moving in the lines of their major axes.*

These facts formed the basis of the history of the formation of our lake basins which I then reported.

This history may be briefly epitomized as follows :—

1st. In the Tertiary age a great river traversed and drained the basin of the lakes, rising in the highlands north of Lake Superior, and terminating in the Atlantic ocean eighty miles south and east of New York.

2d. In the advent and decline of the Ice period, local glaciers descending from the Canadian highlands and following the lines of lowest level, scooped out expansions of the river valleys forming the basins of the present lakes.

3d. These basins were connected by cañons which cut the rock barriers separating them, and through which flowed their surplus waters.

4th. At the culmination of the Ice period a general ice sheet filled and overflowed the lake basin, choking up the river valleys with boulder clay, and obliterating the details of local topography.

5th. After the retreat of the glaciers the great river which drained the lake basin, finding its old channel obstructed, chose for itself a new route. Following the line of lowest levels it left its former trough buried under the Grand Sable, to cross a spur of the Canadian highlands at Sault St. Marie, again it crossed a point extending northward from the Alleghany highlands at Niagara, and, finally, its Mohawk channel being obstructed it chose a new route by the Thousand Islands and Lachine Rapids to the Gulf of St. Lawrence.

A large number of facts sustaining these conclusions are given in the papers to which reference has been made, but a repetition of that which has been so fully stated would be superfluous here.

In tracing the course of the ancient river which drained the lake basin, I ventured to predict that a buried channel would be found connecting the basins of Lake Erie and Lake Ontario, "somewhere between Long Point and the western end of Lake Ontario."

This channel Prof. J. W. Spencer, of King's College, Windsor, N. S., claims to have discovered; and in a paper published in the last issue of the Proceedings of the American Philosophical Society, he maps and describes it, locating it where I had predicted its discovery, although he says it is a

*The first suggestion of the existence of these ancient buried channels was given by the borings for oil in the valley of the Cuyahoga at Cleveland, where I then resided, and in the valleys of other tributaries to the Lake system or the Ohio. Every stream bed in that section was at that time probed for petroleum, and in most cases the rock bottoms of the valleys were only reached after penetrating a considerable mass of clay beneath the present stream. At Cleveland the rock bottom of the old valley is two hundred feet below the bottom of the river, and the lake basin into which it flows, though silted up to within sixty feet of the surface of the water, was once excavated to a still greater depth than the river trough.

channel "of which there was no clue or even suggestion until working up the origin of the Dundas valley." Prof. Spencer also does much more than describe this buried channel in the paper referred to, for he there discusses at length the origin of the lake basins, and reaches conclusions which are in some respects at variance with those previously published by myself.

The points of difference between us are briefly these; I had claimed the existence of an ancient river flowing from Lake Superior through the lake basin and down the Mohawk valley into the trough of the Hudson, and thence to the ocean by New York. The valley of this stream, locally expanded into boat-shaped basins by glacial action, according to my view, formed the basins of the great lakes.

Prof. Spencer denies that glaciers have played any part in the formation of the lake basins, and more sweepingly that ice has any excavating power. He also rejects the theory that the outlet of the lake basin was by the Mohawk valley, saying, "the Mohawk course will not answer as the Geological Survey of Pennsylvania has shown, for at Little Falls, Herkimer Co., the Mohawk flows over metamorphic rocks."

Meeting the last objection first, I venture to say that the Geological Survey of Pennsylvania has not shown that the outlet of the lake basin through the Mohawk valley "wont do." The fact that the present Mohawk river flows over rocks at Little Falls is no new discovery, as it could hardly escape the observation of any traveler over the New York Central Railroad, but there is ample room in the adjacent country, where heavy beds of drift cover the rock, for the continuation of the old, deeply-cut Mohawk valley. In the country about Little Falls, not only is there room for such a channel, but the facts necessitate its existence. The rocky barriers over which the Niagara and St. Mary's flow are equally conclusive evidence against a continuous buried channel connecting the great lakes,—in which we both believe.

In regard to the agency of glaciers in excavating the lake basins I think no one who will carefully observe the facts, will hesitate to ascribe to them an important function. It is true that Prof. Whitney denies that ice has ever excavated a lake basin, and Prof. Spencer echoes and endorses the statement; but it is also true that Prof. Ramsay, Director of the Geological Survey of England, claims that *all* lake basins have been excavated by ice, and Prof. J. Le Conte whose range of observation has been extensive, attributes the origin of Lake Tahoe and other lakes in the Sierra to this cause. They have also supported their views of the power of ice as an erosive agent, not simply by the authority of their names, but by an imposing array of facts. In such circumstances those who deny any excavating power to glaciers can hardly expect their curt dismissal of the ice theory to be accepted without some sort of evidence beside their personal assertion. It has happened to me to have opportunities of studying the effect of glaciers ancient and modern in many countries, and I am compelled to say that the statements that ice has no erosive power, and has made no im-

pression on topography except by the accumulation of morainic material, and also that ice has had no agency in the excavating of the lake basins, are alike disproved by my own observations. Any one who has visited the present termini of the Alpine glaciers cannot fail to have remarked the *roches moutonnées* and the broadly excavated troughs, the work of the glaciers when they had greater reach. He will also have noticed that these glacial troughs, under and beyond the present glaciers, are furrowed by deep and narrow channels, the work of the streams flowing from the melting ice. Here we obtain conclusive evidence that ice *has* erosive power, and have, on a small scale, typical examples of the kinds of erosion wrought by ice and water. The higher portions of the Sierra Nevada, and the whole summit of the Cascade mountains bear such indisputable evidence of the erosive action of ice that it is incomprehensible that any one should have seen this record and deny its validity. On the Cascade mountains there are thousands of square miles over which the rocks are planed down, grooved and furrowed, where the rough and ragged summits are reduced to *roches moutonnées* and enough material has been removed by ice to fill all the water-cut channels of the continent. In the Report of the Geological Survey of Ohio I have described in detail the evidence of the action of ice in forming the basin of Lake Erie. No one can visit the group of islands off Sandusky without being convinced that they are carved by ice out of the solid rock. Their sides and surfaces are everywhere glaciated, and areas of acres in extent planed down to the smoothness of a house floor. The corals and other fossils which fill the limestone are here cut across as smoothly as it could be done by hand ; and as I have elsewhere shown, the direction of the furrows and the trails left behind chert masses in the limestone, prove that the ice moved in the line of the major axis of Lake Erie, and from the north-east toward the south-west. Similar facts both in regard to rock striation and the transport of material have been observed about Lake Ontario, Lake Huron, Lake Michigan and Lake Superior.

The manner in which ice accomplishes the erosion effected by it, is no mystery, as any one who has seen a glacier has seen the agent in action. The soft ice simply becomes a great emery wheel. Rocks, gravel and sand are frozen into its under surface or are spread beneath it and pressed down upon its bed with the enormous weight of the moving mass ; the result is a grinding that nothing can resist. The ground up material is "till" or boulder clay, sand, gravel and boulders, and this residue, perhaps insignificant in quantity compared with the amount produced, covers literally hundreds of thousands of square miles on this continent alone. How, in the face of these facts, can any one say, ice has no erosive power? Prof. Spencer misunderstands and misrepresents me when he imputes to me any vacillation of opinion or any uncertainty in regard to the agencies which have excavated the lake basins. From the first I have recognized the existence of an ancient river draining the lake basins at a low level, and was by many years the first to indicate the existence of such a stream, but

I have never for an instant doubted that the erosive action of this river was supplemented and modified by local glaciers. It is quite beyond the reach of fluvial erosion,—of which in the cañons of the Colorado, I have studied the best examples extant,—to form basins like those of our great lakes; and while it gives me pleasure to find in Prof. Spencer's discovery a confirmation of the prediction made years ago, and to give him credit for the sagacity and industry which marks his investigations, I cannot but feel that before attempting to write a general history of the Lake basins, it would have been well to have gone in person over all the ground under discussion.

*Discussion.*

Mr. Lesley remarked that in all controversies over the Glacial hypothesis, as it used to be called, the Glacial theory as it has now well established itself to be, a vast number of observed facts are accepted on all hands as part of the actual human knowledge. No one now thinks of disputing the former extension of existing glaciers; nor the former existence of sheets of ice over large areas of the earth's surface, where nothing like a glacier is now noticeable even at the close of the severest winters; nor the meaning of the scratches and grooves, clays and gravels, moraines and kames, pot holes, ponds, terraces, sand dams, reversed drainage, and whatever else are the characteristic marks and vestiges of the agency of the ice which once covered such areas. All geologists who have studied existing glaciers in the Alps, for instance, or who have acquainted themselves with their character and action through good descriptions of them, take precisely the same view of the circumstances.

What geologists are not yet agreed upon is not whether moving ice once covered now fertile districts, but the precise limits of these glaciated districts; not that all moving ice moves rocks, but precisely in what manner the rocks move with, on, in or under the ice; not that glaciers deposit heterogenous materials, but precisely what part water, melted ice, plays in the drama, and how one can best distinguish its work from that done by the ice itself, unmelted, in and of itself; not whether there has been an age of ice, but whether there were not two or more, and whether human beings began to live in an earlier, in a medial, or in a later age; and above all, not whether the surface of glaciated regions was modified by the long or short, single or repeated passage of ice over them, but precisely to what extent this modification went.

In a word, the Glacial Theory, perfectly well defined and accepted by all in the clear light of long continued, thorough and consistent investigation, is still surrounded by a penumbra of Glacial Hypotheses, about which very enthusiastic and dogmatic geologists are disposed to debate with a great deal of personal warmth, as if their personal reputation for genuine scientific ability was involved. The fact is, some of the questions thus presented are so difficult of any precise definition that we must wait long for their answers.

The most difficult of all these questions has naturally excited the most strenuous discussion :—the excavatory power of ice.

Every geologist knows that an uncertain amount of erosion must be explained by ancient ice movements ; for, the eroding action of glaciers may be studied in Alpine valleys as it is now going on. But some think this erosion to be so insignificant as to be justly compared to the sandpaper smoothing-off of a roughly-planed board ; while others please their imaginations with its incredible force and magnitude, and describe it as ploughing out Alpine valleys, and excavating American lakes. Recent works on the Glacial Age might be quoted to show that conjectures of all grades between these two extremes are accepted by their geological authors—vague postulates, or general propositions, taken for granted, without being subjected to any mathematical analysis—as a groundwork for the consideration and description of old and new local facts.

It is needless to say that no personal sentiment on the subject can have a scientific value. For my own part, I entertain a lively persuasion in favor of the sandpaper end of the series of hypotheses ; but I can assign no higher value to this persuasion, or personal opinion, nor do I think it can any more efficiently secure scientific results, than an impulse towards the opposite, or lake excavating prejudice. It is after all merely a prejudice, but a prejudice in favor of the preponderance of a multitude of facts which bear upon the subject under discussion ; facts which I think have never yet been placed in the strongest light ; facts of topography, especially abundant in regions near to but outside of glaciated regions.

There are two principal lines of investigation, it seems to me, which may lead us to a hopeful elucidation of the question of *how much of our topography has been effected by ice.*

1. We may take up one feature of topography after another, and by a process of exclusion, narrow down the field of ice-action until what is left shall remain reasonably certain to be due to ice alone ; and

2. We may study, directly and mathematically, by number, weight, bulk and velocity, the work actually done by an existing glacier, and infer by strict comparison the possible limits of ice-work over any given glaciated region.

Thus, to take the last first, let us ask what is the potential of eroding energy in the case of a glacier?

Pure ice, of course, has no scratching power. The facility with which it moulds itself upon surfaces, is shown, in an astonishing manner, by grooves on the underside of a moving glacier, produced by large stones lying quite loose upon the bed-rock, and prevented from slipping forward with the ice by some slightly obstructive irregularity of the bed-rock surface. The common notion is that all such stones are necessarily embedded by the ice and used as scratchers, or eroding tools. But at least some of them are not so taken up by the ice, which slips smoothly over them, retaining as a groove the shape of their cross section, for many yards after passing their position.

The number of stones thus inoperative at the base of a glacier is one of the factors in the equation of erosion.

That ice uses sand, gravel and boulder débris to scratch its rock bed is not doubted by any one. The abrupt termination of striæ, deepening and widening to their abrupt termination, was one of the earliest observed facts, and was explained on the old diluvial theory, and the iceberg theory, by the arrest and rotation of the block which served as a graving tool, fixed in the ice, or by the breaking off of the point of the tool.

The chapters of James Hall's Report of the Geology of the Western District of New York, published in 1844, which describe the Drift and Glaciation of that District suffice to show how carefully these phenomena were studied fifty years ago. Dr. Newberry and other ultra-erosionists would do well to note what Hall says (on page 331) in evidence of the comparatively slight force necessary for producing the grooves and polished surfaces, the overturning of bed plates, and transport of fragments, from which such exaggerated theoretical consequences are deduced.

In those really admirable chapters may be found the earliest hints of the now accepted activity of subglacial water, loaded with débris, in doing much of the work wrongly ascribed to ice.

The actual erosive power of rock-set ice must certainly be susceptible of an approximately accurate mathematical calculation,

Its differential is: *one stone,* held by the ice against the bed-rock with a certain pressure—the stone of a certain hardness (a)—the bed-rock of a certain hardness (b)—the ice-grasp of the stone, of a certain plasticity (c)—the maximum pressure exerted by the weight of the ice, up to the point-crushing degree (d).

It is evidently wrong to make the total weight of the column of ice above the tool a measure of the engraving. Were the ice piled to the height of miles, its graving power would be no greater than that of a column of ice weighing just enough to crush the point of the tool. All the declamation in books respecting the enormous erosive force of a sheet of ice several thousand feet thick pressing down upon and moving over sandstone, limestone and shale strata is simply wasted. A thousand miles thickness of pure ice moving over a bed of clay, would erode it no more than a thousand miles of water would. If it held stones, they would be simply embedded in the clay and left behind. If they moved over any kind of solid rock, they would simply be reduced to fine sand or mud, and act as a *lubricating medium,* protecting the bed-plate surface from erosion.

Every glacier must slip to a greater or less extent upon a lubricated surface, consisting principally of muddy water, or watery mud. The thicker the glacier the more of this lubricant it will have beneath it. The law of increase of temperature descending from the surface must act in ice as in rock. Where the bare rock surface of the earth has a mean temperature of 32°, the temperature at 1000 feet down stands at, say, 52°. Were a glacier 3000 feet deep to remain for a century immovable over a region the normal mean air temperature of which is

32°,—while it would waste slowly at its surface by spontaneous evaporation, and more rapidly at its surface by solar heat—it would waste at its base also by the upward transmission of earth heat. But this waste would be represented by so much water, which under an immovable glacier would form a lake. Under a movable glacier it helps to form a river, and the river which issues at the terminal surface moraine brings out the evidences of the lubricant, as "mountain meal."

Every glacier must be made cavernous by its river, and along the caverns produced by the river and its branches are collected and deposited or rolled forward all the stones in the glacier while those upon its surface (or melted out to its surface, by the upper waste), ride down to its lower end.

The much larger part of the erosive action of a glacier must therefore be of the nature of river erosion; while a certain percentage of it may be of the nature of engraving. But if so, then our knowledge of river erosion must direct us in the investigation of glacial erosion.

River erosion is local and interrupted. Parts of a river bed are filling up, while reefs and barriers are being cut away. So, under a glacier, the loci of erosion must be few and of limited extent. Behind these the rolled glacial débris are covering and protecting the bed rock instead of eroding it. Our kames show therefore not only that Glaciers are feeble eroders, but that they are great depositors and protectors of the earth surface.

We may go one step further, and show how in the age of ice the usual erosion of our topography was almost stopped and forbidden by the ice.

For, the topography of the earth's surface is evidently due to rain, softening the surface—to rills, removing the softened surface—to brooks, sweeping the collections made by rills, down through the brook-vales and ravines which they have made,—until the process of erosion is reduced to a minimum where river deposits commence. Rivers never erode, except at rock barriers—or, in rainless regions, where they saw strait down, using their whole débris.

Now, in the ice age, the ice-covering protected the whole country from rain, rill and brook erosion, and the process of topographical modification of the earth's surface ceased, and was not resumed until the close of that age. What erosion took place, must have been exclusively confined to the lines of subglacial rivers and their branches, along the subglacial caverns. In a continental ice-flow crevasses were impossible, except along a few lines of escarpment.

The rain, therefore, in the ice age must have constituted a great riseau of superglacial drainage incapable of eroding the subglacial topography; in fact removed from it hundreds and even one or two thousand feet from it vertically. If the Canadian ice had a surface slope southward, towards Pennsylvania and Ohio, or south-westward up Lake Erie and across Illinois, then mighty rivers, heading in the Laurentian mountains and the Adirondacks, must have flowed for a long time over the upper surface of the ice

sheet, southward and south-westward into the Mississippi valley—without affecting the previously constituted topography beneath the ice—of which previously constituted topography the Lake Basins were an essential part and grand feature.

Meanwhile, a totally different system of drainage was carrying on its work of transportation beneath the ice sheet, in an opposite direction, northward (from Pennsylvania and Ohio) and eastward, through the lake basins. But this lower or sub-ice river system, deprived of *direct* alimentation from rain, must have been inferior in volume and power to the upper or surface-ice river system; although it may have received here and there through the ice sheet considerable accessions of surface rain water.

I do not wish to discuss here the line of Prof. Spencer's great river, nor the claim of Prof. Newberry to the discovery, years ago, of its debouchement, via the Mohawk and Hudson valleys, into the ocean at New York, except to remark that Prof. Newberry does not seem to appreciate Prof. Spencer's chief difficulty. It is not that the rocks appear at Little Falls; but that his Ontario river ran in a bed more than 780 feet beneath the present level of the lake, and therefore more than 900 feet below Little Falls, and the demonstration of a buried, concealed, old river channel nearly 1000 feet deep anywhere alongside of the Little Falls exposure seems a rather hopeless task. But worse than that; the Mohawk valley east of Little Falls, is barred by rock ranges 300 or 400 feet high, through which the Mohawk cuts a cañon, where its bed is at least 900 feet above the old river bed in the lake.*

I wish to confine my remarks to the feeble erosive power of the Canadian ice-sheet, as a particularly inefficient kind of glacier, and to the probable possibility of a mathematical demonstration of the feeble erosive power of any glacier, even in the most favorable circumstances.

Taking one stone graving-tool as the differential of *means*;—the engraving quality of that stone tool (under the conditions (a), (b), (c), (d) above stated) as the differential of *power*;—and the destruction of bed-rock by that stone-tool during its life as a tool, as the differential of *effect produced, i. e.* of erosion,—then,—to obtain a transcendental maximum, we must multiply one stone-tool (in area) by the total width and total length of the ice bottom; *i. e.* we must stud the whole bottom of the glacier with tools; keep them all at work, each one for the whole length of time of its descent from the upper to the lower end of the glacier;—replace those that are lost or spoiled by fresh ones;—and repeat the operation during the entire life of the glacier.

It is evident that this transcendental maximum if it could be calculated, would be of little value, in as much as it would almost infinitely exceed the actual practical erosive power of any given glacier.

But it would be the best starting point for a reasonable discussion of the erosive power of glaciers; and it seems to me, that if the calculation were

*See my notes to Dr. Spencer's appendix, at the end of White's Report of Progress, 2d. Geol, Sur. of Pa., Q. 4, 1881, p. 403.

made, it would have the effect of putting a stop to much of that vague babble about the "immense" "enormous" "amazing" influence of the ice age in sculpturing the surface of our planet, which has in some respects demoralized our science.

Had the age of ice commenced in Laurentian days or even in Permian times and lasted until now, we should certainly be compelled to ascribe most of our topography to the action of ice. But as the ice age was late and comparatively short, we must consider its effect upon our topography not only local but slight.

The second line of argument, therefore, is a very simple one. We should enquire first, what are the main features, the characteristic elements of our topography; and secondly, whether those be essentially the same in the glaciated and in the nonglaciated regions. If we find them to be identically the same in both regions, then, it follows, as a matter of course, that they cannot be ascribed to ice.

This line of argument I have taken numerous occasions, in past years, to follow out, and I have shown that the great lake basins of the north are in all (but one respect) topographically like the great valleys of the south and therefore *not* excavated by ice. The one item of exception is, that they have been more or less filled with the débris of the ice sheet, and afterwards with water dammed in behind glacial deposits. So far from the glacier having excavated them, it has simply buried them.

The argument pursued on this grand scale, repeats itself on a small scale now that the Terminal Moraine has been traced across the mountains and valleys of New Jersey and Pennsylvania. If the glacier covered the top of the Kittatinny mountain, for example, along its whole course from the Hudson to the Delaware, and for some miles west of the Delaware, and did *not* cover it anywhere along its whole course through Pennsylvania, Maryland and Virginia (and these facts are now demonstrated)—and if, notwithstanding, the mountain in its north-eastern prolongation is precisely the same as in its south-western prolongation—it follows without argument that it existed in its present form before the ice age, and was merely a little *sandpapered* by the ice during the ice age.

What is true of the Kittatinny, is true of the (Catskill) Pocono mountain plateau behind it, and of the Orwigsburg or Delaware river (Upper Silurian and Devonian) valley which separates the two ranges. Across this broad valley (the analogue of Lake Erie) the Terminal moraine runs west of Stroudsburg. The topography of the valley east of the moraine precisely resembles the topography of the valley west of the moraine, only that it is covered with drift material and marked with scratches. Of course the valley existed before the ice age, and the glacier merely polished its surfaces and *protected parts of it from subsequent erosion;* just as the glacier *protected lake Erie from erosion,* while it scratched the islands of which Prof. Newberry speaks, and all the hard outcrops, around it, as described by James Hall in New York, by Carll, White and others in Pennsylvaina, and by Dr. Newberry in Ohio.

And so of each valley and each mountain successively as one follows the terminal moraine north-westward, across the gorge of the Lehigh, across Hellkitchen mountain, across Conyngham valley, across the Nescopee mountain, across the Susquehanna above Berwick, across the Schickshinny mountain, near its west end, across the Muncy hills, across the Alleghany mountain north-east of Williamsport, across the Loyalsock ravine, and the Cañon of Lycoming creek, the plateau of Potter county, to its great angle north of Olean and Salamanca in New York.

Along this whole line, the topography to the east (under the ice) is precisely the same as the topography to the west (where ice has never been) and the only distinction observable is this: that west of the great moraine there is no drift and no lakes; east of the moraine the whole surface is sheeted with drift and spotted with ponds;—and all the scratches point south-south-westward, the ice evidently having moved from the Adirondacks.

From Salamanca the Terminal moraine has been traced by Mr. Lewis and Mr. Wright as a nearly straight ridge of trash, south-westward, across Western Pennsylvania to the Ohio line (near Darlington) 13 miles north of the Ohio river; the scratches all pointing S. S. E. and S. as if coming square across Lake Erie and ascending the highlands to the south of it. Nowhere along this line has it affected the topography; it has merely deposited drift, and choked the ancient valleys so as to reverse the drainage. Mr. Carll has pointed out the noses of hill-spurs which he thinks were sharpened by the ice; but even this slight modification of the pre-existing topography, occurs at places lying outside or to the south of the terminal moraine, and we must therefore find some other explanation for it.

It seems unreasonable in the highest degree therefore to speak of the glacial erosion of Lake Erie and Lake Ontario, when it is evident that the ice sheet was perfectly incompetent to erode the countries which it invaded, and left them everywhere precisely in the topographical condition in which it found them; merely scratching their rock exposures, incumbering and embarassing somewhat their lines of drainage, spreading a slight sheet of drift material over them, and tearing a few blocks out of the looser outcrops and depositing these blocks after a short transit; often on higher levels, and sometimes on much higher levels; for Mr. Lewis has found Helderburg blocks carried completely to the top of the Kittatinny mountain.